THERMAL CONTROL ASPECTS OF SPACECRAFT LOUVERS

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INTRODUCTION

On any given space mission a spacecraft may be subjected to sudden changes in environmental heat loads. These changes may occur because of varying exposure to solar and planetary irradiation sources or through variation in the internal heat dissipation of the experiment package. In order to keep the spacecraft temperatures within design limitations some type of control deivce must be used. One method of controlling the temperature of a spacecraft is by the use of a louver system (1,2). The louver system consists of movable blades pinned to the spacecraft surface or placed between the instrument package and the outer skin of the spacecraft. The blades are connected to a device which changes their position as needed.

Very often the louvers are mounted such that they protect either a white diffuse solar reflecting surface or an opening to the "black" interior of the spacecraft. The latter case has its application when the louvers are to operate in the shade. The operational characteristics of louvers are known for this case by experiment (3). However, louvers used in sunlight necessitate a surface with a high solar reflectance between the louvers and the electronic packages. It has been shown that even with a highly reflective surface between the package and the louver system, lineraly activated louvers will not control the package temperature satisfactorily in all cases (4,5).

By placing a skin over the louvers to reflect sunlight, the problem is overcome. However, when the spacecraft orientation is such that the louver panel is in the shade, the skin will act as a thermal barrier to radiation. The net effect of the skin is to reduce the net heat rejection capacity of the system in the shade while improving the heat rejection characteristics in the sunlight. Thus in some cases it may be necessary to sacrifice spacecraft maneuverability so as to avoid direct solar impingement in order to have the capacity of rejecting large amounts of heat with external louvers. In other cases it may be possible to gain improved maneuverability by sacrificing maximum heat rejection capability and using internal louvers.

Consideration must also be given to the effect of heat transfer from diffusly emitting surfaces (e.g. solar panels) to the temperature control panels of the spacecraft. This is a rather simple effect to determine for internal louvers. However, the radiant heat transfer to external louvers is a very strong function of blade angle and the relative position of the diffusely emitting surface to the louvers.

GRANT ACTIVITIES

The digital computer program presented in reference 4 has been modified. These modifications include: 1) the heat rejection analysis of internal louvers, 2) a variable base plate temperature input, 3) additional heat input to the outer skin of internal louvers from sources other than the sun, 4) provisions for including the effect of heat input to external louvers from diffusely emitting surfaces. A description of the revised input and output are presented in Appendix B.

A separate program has been generated which determines the heat input to external louvers from diffusely emitting non-isothermal panels.

DESCRIPTION OF THE INTERNAL LOUVER SYSTEM

A diagram of the internal louver system is shown in Figure 1. In general, the configuration of Figure 1 would have the following characteristics. 1) The outer skin would have as low a solar absortpance as possible while having as high a terrestrial emittance as possible. 2) The interior surfaces of the skin would have a black coating of high emittance. 3) The louver blades would be of a highly polished, specular material having an extremely low emittance. 4) The blades would be as thin as practical. 5) The mounting plate emittance would be as high as possible.

A louver position is adjusted by a mechanism in accordance with the heat rejection needs of the spacecraft system. If the temperature of the mounting plate rises, the louvers open reducing the resistance to heat flow from the mounting plate to the skin. If the temperature should fall below a certain value the louver blades close, forming a highly reflective barrier to heat loss from the mounting plate.

ANALYSIS OF THE INTERNAL LOUVER SYSTEM

Assumptions:

1) All surfaces are isothermal

2) All surfaces are isoradiametric

3) The blades are of high enough conductance so that both sides may be considered at the same temperature

4) The material properties are different for solar and terrestrial radiation, but in general $\alpha_{\Delta_\lambda} + \rho_{\Delta_\lambda} = 1$

5) The surfaces are thermally coupled by radiation only.

6) The louver system is an infinite array so edge effects are negligible.

A heat balance for each of the surfaces yields the following set of equations.

$$Qnet_3 + \alpha_3 \left(J_4 F_{(4-3)T} + \varepsilon_{1,2}\sigma T_{1,2}^4 (F_{(1-3)T} + F_{(2-3)T}) + J_3 F_{(3-3)T}\right) - \varepsilon_3 \sigma T_3^4 = 0 \qquad 1$$

$$\alpha_1 \left[J_4 F_{(4-1)T} + J_3 F_{(3-1)T} + \varepsilon_1 \sigma T_1^4 \; F_{(1-1)T} + \varepsilon_2 \sigma T_2^4 \; F_{(2-1)T}\right] + \alpha_2 \left[J_4 F_{(4-2)T} + J_3 F_{(3-2)T} + \varepsilon_2 \sigma T_2^4 \; F_{(2-2)T} + \varepsilon_1 \sigma T_1^4 \; F_{(1-2)T}\right] - 2\varepsilon_{1,2} \sigma \; T_{1,2}^4 = 0 \qquad 2$$

$$G + \alpha_4 \left[J_3 F_{(3-4)T} + J_4 F_{(4-4)T} + \varepsilon_{1,2} \sigma T_{1,2}^4 \; (F_{(1-4)T} + F_{(2-4)T})\right] - \sigma(\varepsilon_4 + \varepsilon_5) \; T_4^4 = 0 \qquad 3$$

Where the radiosity is:*

$$J_4 = \rho_4 \; [J_3 F_{(3-4)T} + \varepsilon_{1,2} \sigma \; T_{1,2}^4 \; (F_{(1-4)T} + F_{(2-4)T}) + J_4 F_{(4-4)T}] \qquad 4$$

$$J_3 = \rho_3 \; [J_3 F_{(3-3)T} + \varepsilon_{1,2} \sigma \; T_{1,2}^4 \; (F_{(1-3)T} + F_{(2-3)T}) + J_4 F_{(4-3)T}] \qquad 5$$

If all of the radiant properties, G, and T_3 are known, the above equations may be solved for the unknown temperatures and $Qnet_3$ for any louver position θ. The net heat transfer at surface 3 may be found by use of an equivalent thermal resistance for the system: since;

$$Qnet_3 = \frac{Eb_3 - Eb_4}{R} \text{, and} \qquad 6$$

$$\frac{Eb_4}{1/\varepsilon_5} = G + Qnet_3 \qquad 7$$

The net heat transfer is:

$$Qnet_3 = \frac{Eb_3 - G/\varepsilon_5}{R + 1/\varepsilon_5} \qquad 8$$

* A totally specular surface does not have a radiosity (J) associated with it in the ordinary sense.

The thermal resistance R is a function of the radiative material properties of the louver blades and the louver position. The term $Eb_3/\ (R + 1/\varepsilon_5)$ represents $Qnet_3$ for G = 0 therefore, equation 8 may be written:

$$Qnet_3 \Big|_{G = P} = Qnet_3 \Big|_{G = 0} - P\ f(\theta, \varepsilon_5) \tag{9}$$

where $f(\theta, \varepsilon_5) = (\varepsilon_5 R\ (\theta) + 1)^{-1}$

Equation 8 may also be written:

$$Qnet_3 = (\varepsilon_5\ Eb_3\ - G) \quad f(\theta, \varepsilon_5) \tag{10}$$

RESULTS OF INTERNAL LOUVER ANALYSIS

Figure 2 shows $f(\theta, \varepsilon)$ for the case where; $\varepsilon_5 = .75$, the interior surfaces 3 and 4 are painted black ($\varepsilon = .87$) and the blades are made from polished aluminum ($\varepsilon = .05$). The use of the chart may be demonstrated by an example problem.

Suppose the experiment requires the rejection of 2BTU/HR to 20BTU/HR for each square foot of active louver area. At the same time heat absorbed by the exterior skin from all sources will vary between 0 and 50BTU/HR for each square foot of active louver area. The problem is to determine the maximum temperature variation of the package and the temperature set points for open and closed louvers. For the highest temperature limit we assume the desired heat rejection rate is 20BTU/HR-FT^2 and the absorption rate is 50BTU/HR-FT^2 . From figure 2 we find $f(\frac{\pi}{2}, .75) = 0.5$. Then from equation 10:

$$Eb_3 = \frac{Qnet_3 + G\ f(\theta, \varepsilon)}{E_5\ f(\theta, \varepsilon)}$$

$$Eb_3 = \frac{20 + (50)\ (.5)}{(.75)\ (.5)}$$

$$Eb_3 + \sigma T_3^4 = 117$$

$$T_3 = 513^{\circ}R$$

The louver temperature limit is calculated in a similar manner using a required heat dissipation of 2 BTU/HR-FT^2 and an overall heat absorption rate of 0 BTU/HR-FT^2. The base temperature is found to be 486°R. Thus it is found that the temperature variation for the given conditions can be held to 27°R.

This same analysis is accomplished very easily using curves such as those shown in Figures 3 and 4. Figures 3 and 4 show the relationship between Qnet3, T_3 and louver blade angle for a given heat absorption rate. Under the same conditions as the previous example the maximum temperature can be found from Figure 4 (P=50) simply by following the $\theta=90°$ curve until the desired heat rejection rate of 20BTU/HR-FT^2 (5.9 WATTS/FT^2) is reached, and then reading the base temperature, T_3 on the absissa. By following this same $\theta=90°$ curve the excursion in base temperature corresponding to an excursion in heat generation can be found.

Likewise, the lower temperature limit can be found from Figure 3 (P=0) by following the $\theta=0$ curve until the heat rejection rate of 2 BTU/HR-FT^2 (.59 WATTS/ft^2) is reached and reading the base temperature, T_3 on the absissa.

This example assumed that the louvers just reached the fully open position under the most severe conditions. It is possible to obtain a much finer control on temperature within certain nominal operating regions without increasing the maximum base temperature under "worst case" conditions. This is shown in Figure 4. Consider a case in which normal operation required between .1 and 4 WATTS/ft^2 heat dissipation at the same time the skin is absorbing 50 BTU/HR-FT^2. However, "worst case" conditions might require a heat dissipation rate of 8 WATTS/ft^2 at the same rate of skin absorption. By setting the louvers to reach the full open position at 4 WATTS/ft^2 (point B) the maximum temperature would be 494°R. The operation line of this set of louvers would be ABC. If on the other hand the louvers were set to reach the fully open position at 8 WATTS/ft^2, the louvers would operate along line AC. It is apparent that the required base temperature for a given heat dissipation rate is always lower along line ABC than along AC.

HEAT INPUT TO A LOUVER SYSTEM FROM A DIFFUSELY EMITTING SURFACE

The effect of heat input from diffusely emitting surfaces such as solar panels has a significant effect on thermal control, especially when solar input is small. The analysis of this effect is relatively simple in the case of internal louvers since it only involves radiant heat transfer between two diffuse surfaces.

The anlysis for external louvers becomes more involved since it involves a diffuse radiant input to a specular diffuse system. In this case the energy absorbed by the base plate of the louver system is a function of blade angle, θ, and of the dehedral angle , ϕ, formed by the plane of the incoming energy and a plane through the axis of blade rotation perpendicular to the base surface (figure 5). The functional relationship between effective absorptance of the louver system and the blade and dehedral angles is illustrated in Figures 6 and 7. It should be noted that the absorptance of the blades is very low except at angles of incidence where the radiation intensity is very small. Therefore the effect of IR absorption by the blades can be neglected.

In general the heat absorbed by an incremental area of the louver system (dA_1) which originates at an incremental area of a diffusely emitting surface (dA_2) is

$$Q_{dA_2\, dA_1} = \varepsilon_2 \sigma T_2^4 \; F_{dA_2 - dA_1} \; \alpha(\theta,\phi)\; dA_2 \qquad 11$$

where

$$F_{dA_2\, dA_1} = dA_1 \cos \beta_1 \cos \beta_2 \,/\, (\pi r^2) \qquad 12$$

Substituting (12) into (11)

$$Q_{dA_2 - dA_1} = \varepsilon_2 \sigma T_2^4 \; \alpha(\theta, \phi) \cos \beta_1 \cos \beta_2 \, dA_1 \, dA_2 \,/\, \pi r^2 \qquad 13$$

If a coordinate system is chosen as shown in Figure 8, equation (13) may be put in the form

$$Q_{dA_1 - dA_2} = \frac{\varepsilon_2 \sigma T_2^4}{\pi} \; \frac{C\, Y2\, \alpha(\theta, \phi)}{D} \; dA_1 \, dA_2 \qquad 14$$

where

$\bar{A} = X1-X2 \cos$

$B = Y1-X2 \sin$

$C = X1 \sin - Y1 \cos$

$D = Y2^2 + \bar{A}^2 + B^2$

By integrating (14) over the area of the diffuse emitter and the area of the louver panel the heat absorbed by the louver panel may be found. A digital computer program has been written which carries out this analysis. The program allows for an arbitrary orientation between the emitting surface and the louver panels and for a non-isothermal emitting surface. The program is described in detail in appendix A.

WORK IN PROGRESS OR PLANNED

Currently an anlysis of a louver system consisting of a high emissivety specular base, and diffuse blades is being performed. This type of system is expected to yield a lower effective absorptance to incoming solar energy. The specular base will be coated so as to increase its emittance to a value comparable to a white diffuse surface. Although the base emittance can be held essentially the same and the solar absorption can be reduced with this type of system, the overall performance may or may not be improved depending on the effective emissivety of the system.

One other possibility to be examined is the roughening of the specular blades to make them diffuse to solar energy but specular to terrestrial energy.

Also under consideration is an all specular system. It is known that an all specular cavity exhibits a higher effective emissivity than an all diffuse cavity (6). The effective absorption of this type of system has yet to be determined.

In general, it is planned to investigate louver systems with various combinations of material properties in order to optimize their operating characteristics.

NOMENCLATURE

Arabic Symbols

E	-	Emissive power BTU/HR-FT^2
F_{1-2}	-	Diffuse view factor from surface one to two
$F_{(1-2)T}$	-	Total imaged view factor from surface one to two**
G	-	Heat absorbed by the skin from all sources in the environment BTU/HR-FT^2
J	-	Radiosity of a diffuse reflecting surface BTU/HR-FT^2
P	-	Symbolizes numberical value of G
Qnet	-	Heat dissipation capacity of the mounting plate
R	-	Radiant thermal resistance
T	-	Temperature ^oR
X1,X2,Y1,Y2	-	Coordinates for describing relative position of louver panel and diffusely emitting surface

Greek Symbols

α	-	Absorptance
β_1 β_2	-	Angles between the normal to each of two surfaces and the line connecting the two surfaces
Δ	-	Designates increment
ε	-	Emittance
λ	-	Wavelength
ρ	-	Reflectance
τ	-	Stefan-Boltsman constant $.1714 \times 10^{-8}$ BTU/HR-FT^2 $^oR^4$
θ	-	Louver position
$\int$	-	Angular position of diffusely emitting surface

Subscripts

1,2,3,4,5	-	Refers to particular surfaces (Figure 1)
b	-	Indicates black body
s	-	Indicates solar properties
T	-	Indicates total imaged view factor

**The total imaged view factor is discussed in References 1,2,3 and 4

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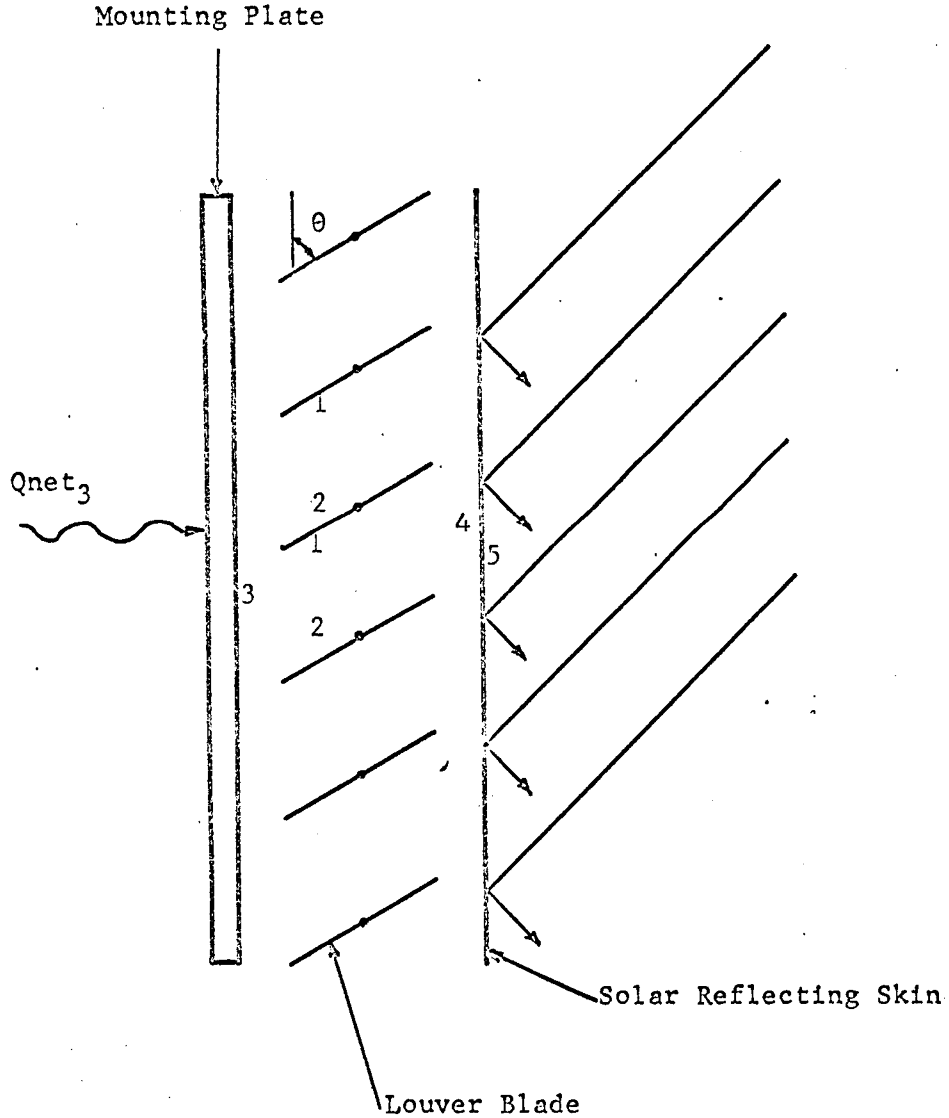


FIGURE 1

Schematic Diagram of Interior Louvers

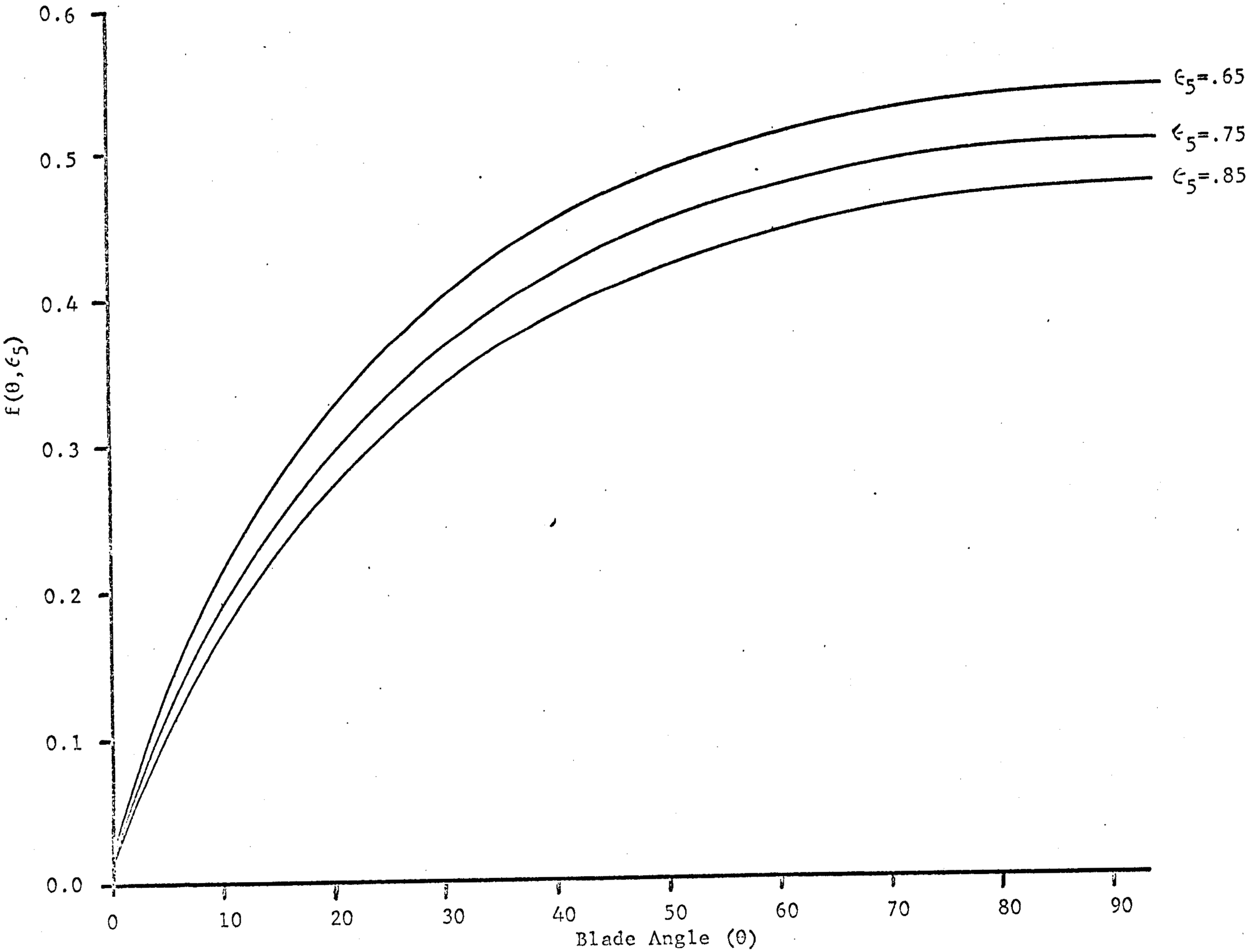


FIGURE 2 - Coefficient of Radiant Transfer

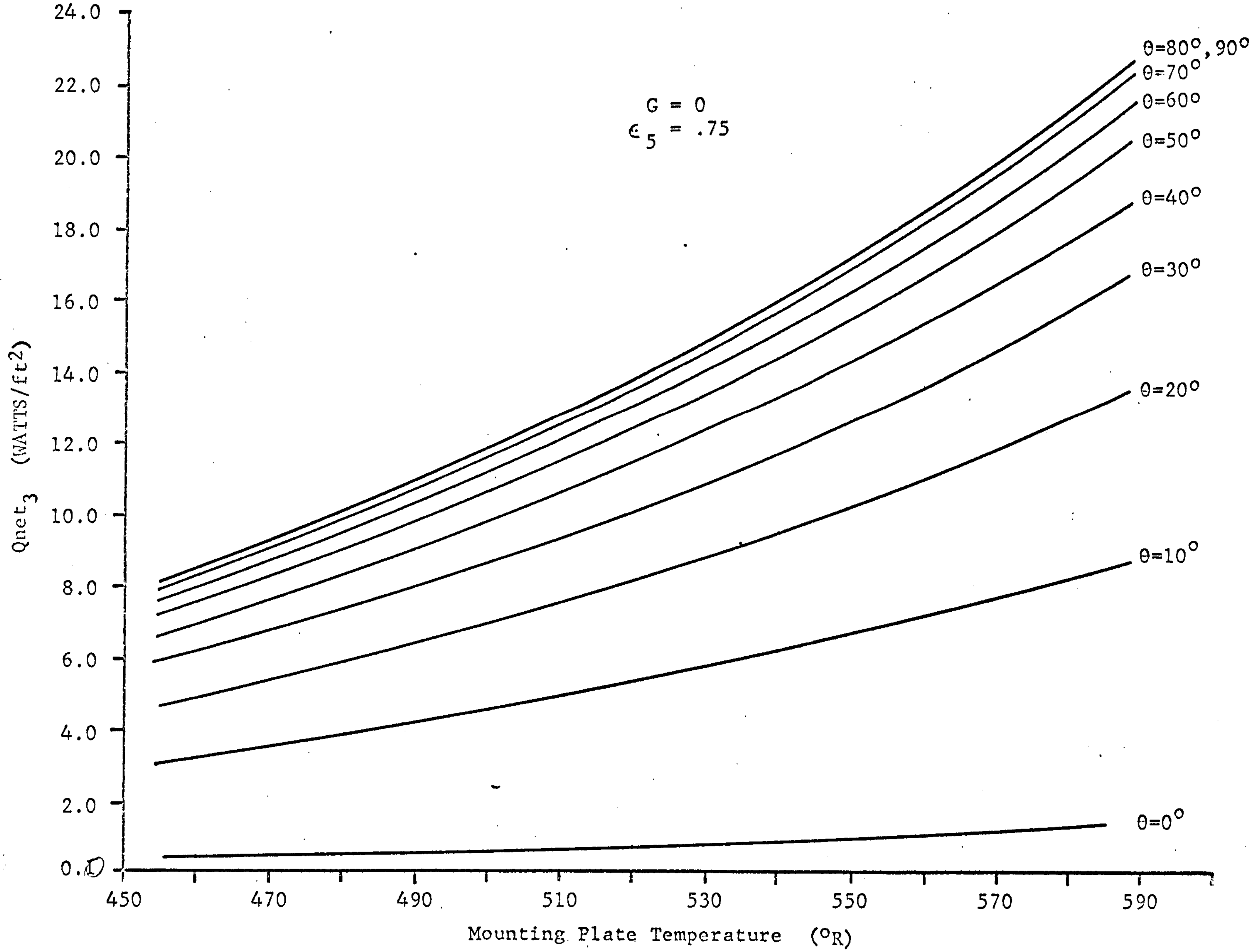


FIGURE 3
Mounting Plate Net Heat Dissipation

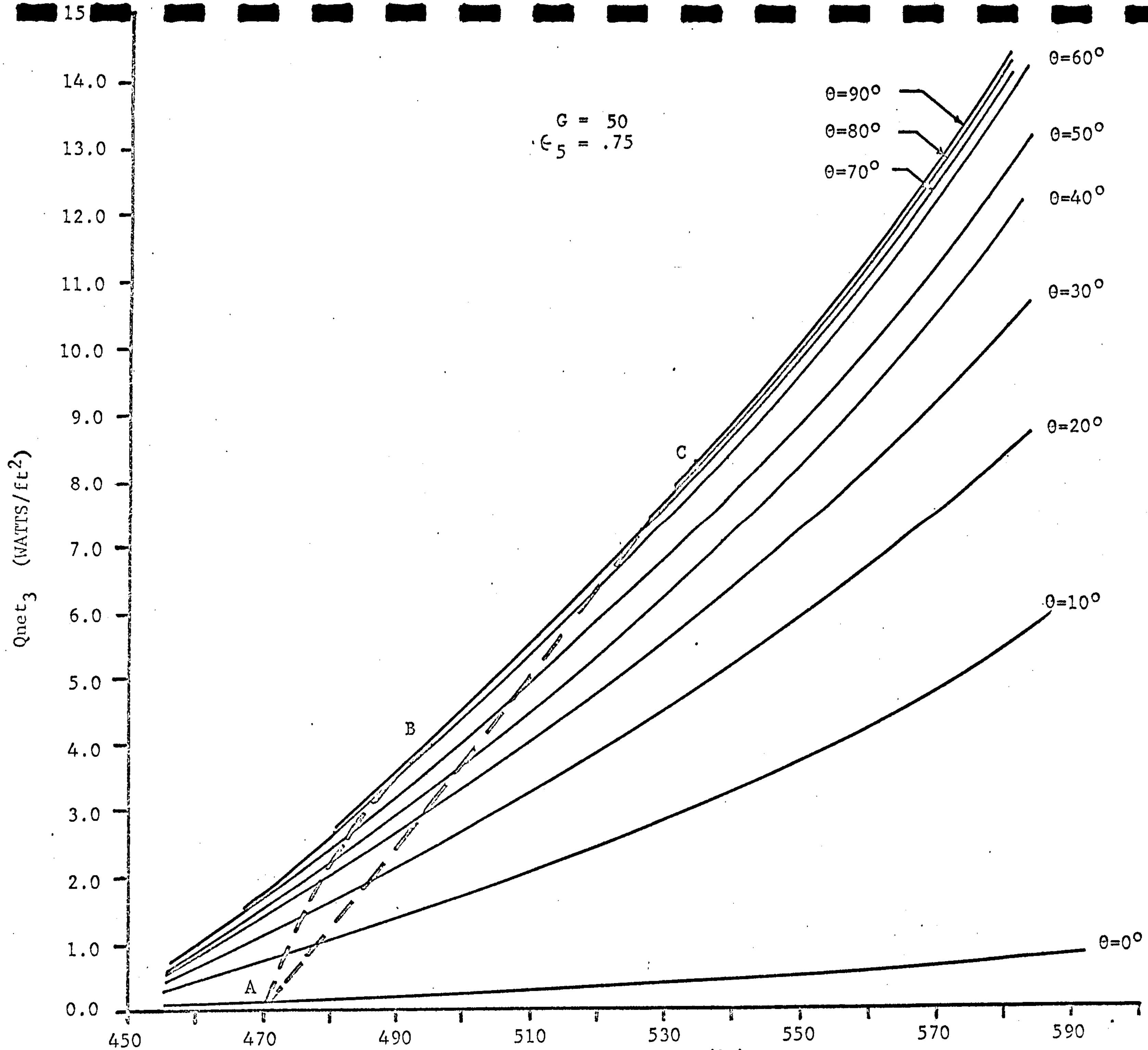


FIGURE 4 - Mounting Plate Net Heat Dissipation

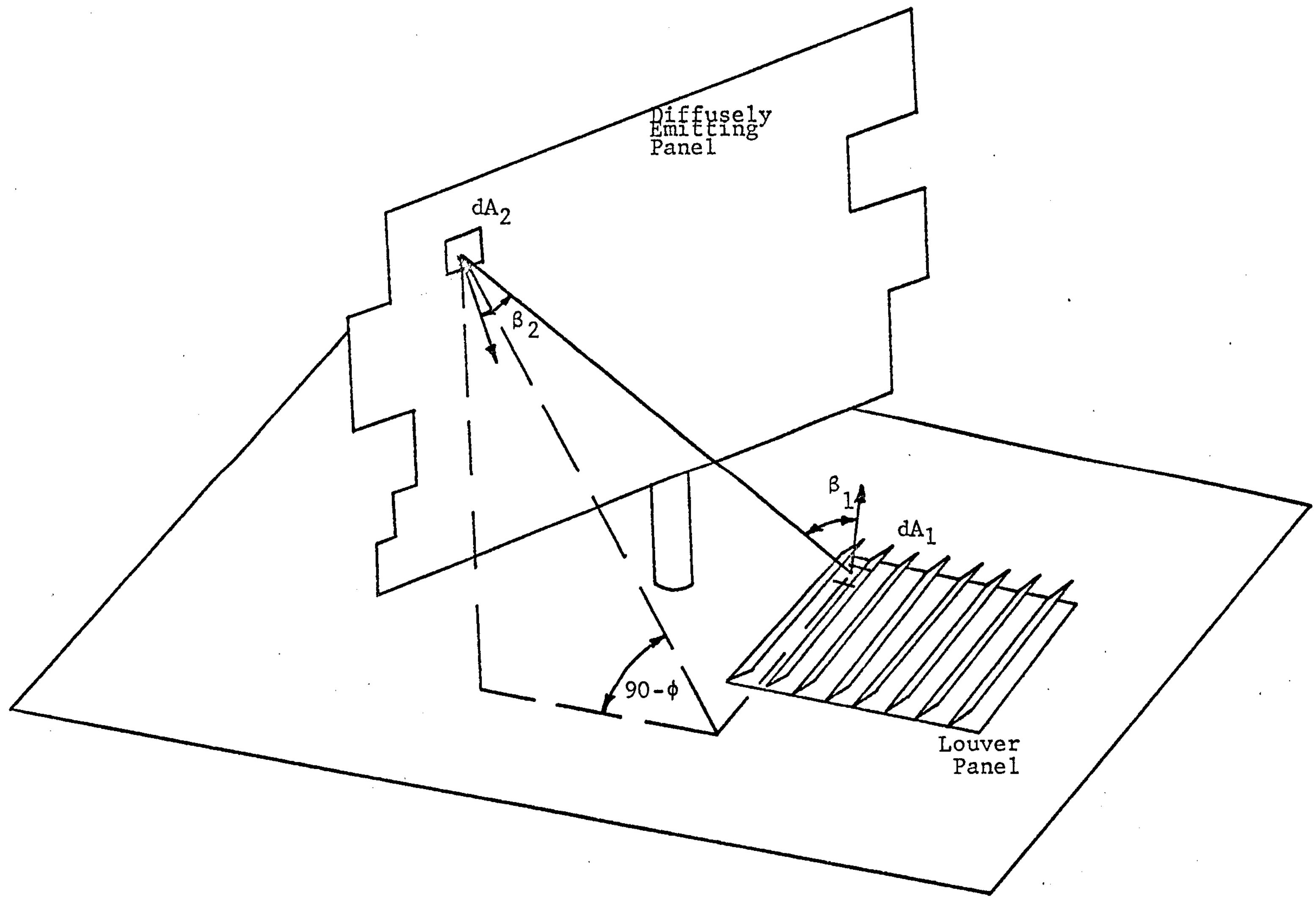


Figure 5 - Typical Solar Panel - Louver Panel Orientation

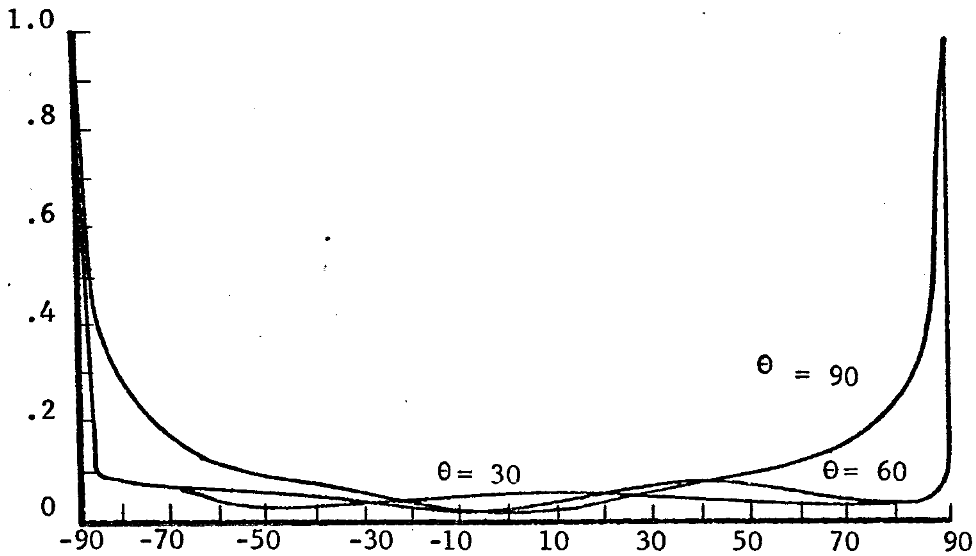


Figure 6 - effective absorption of louver blades

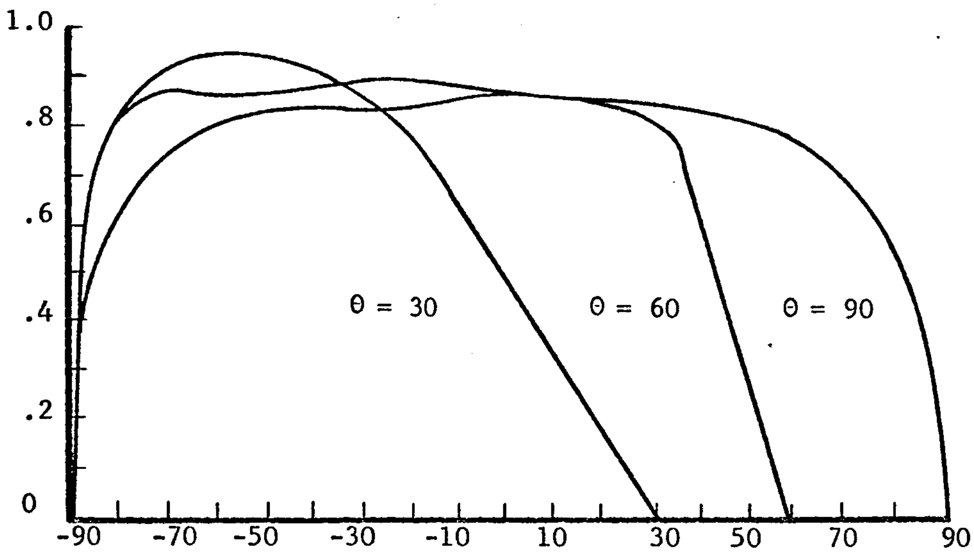
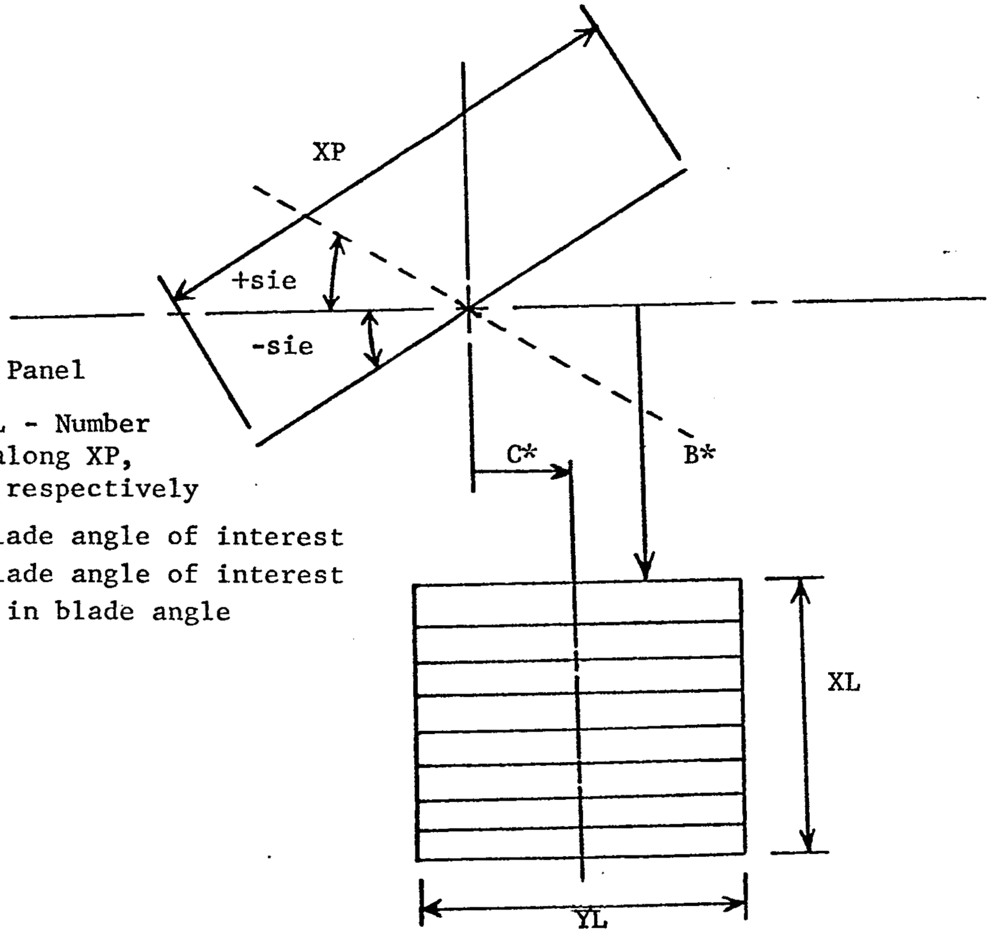


Figure 7 - effective absorption of louver base plate



EP - Emissivity of Panel

XNXP,XNYP,XNXL,XNYL - Number of increments along XP, YP, XL, and YL respectively

THEMAX - maximum blade angle of interest

THEMIN - Minimum blade angle of interest

THEINC - Increment in blade angle

*C & B may be positive or negative

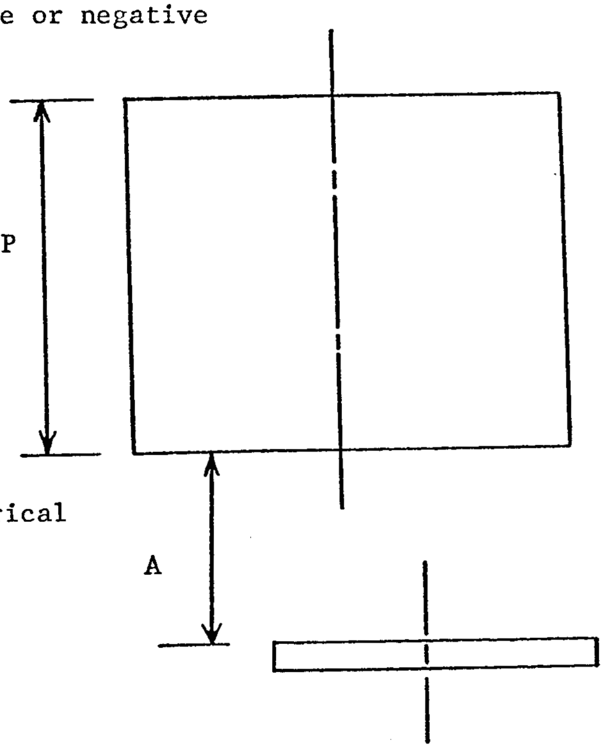


Figure 8 - Legend to Geometrical Input Parameters

APPENDIX A

Digital Computer Program For Heat Input To A Louver Panel From A Diffusely Emitting Surface.

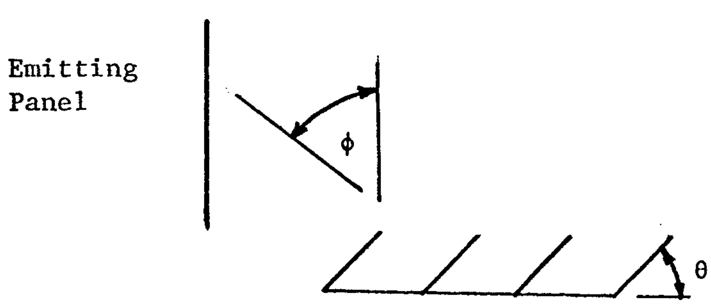
The analysis of a diffuse input to the specular-diffuse louver system was discussed in a previous section. A digital computer program was designed to perform this analysis for a non-isothermal, irregularly shaped, diffusely emitting panel. Finite difference methods are used to accomplish this analysis. In this section the computer program input and output as well as a complete listing of the programs are presented.

Program Input*

A. Effective Absorptance Table

XPITBL	XTHTBL		Card 1
PITBL (1)	PITBL (2) ----------------------	PITBL (20)	Card 2,3,4 (as needed)
THTBL (1)	THTBL (2) ----------------------	THTBL (40)	Cards 5 - 10 (as needed)
ALTBL (1)	ALTBL (2)	ALTBL (800)	Cards 11 - 125 (as needed)

where XPITBL - Number of dihedral angles in the table
XTHTBL - Number of blade angles in the table
PITBL - Dihedral angle between the plane of incoming energy and a plane perpendicular to the lose surface of the louver panel (See diagram below)
THTBL - Lower blade angle (see diagram below)
ALTBL - Effective absorptance of louver base plate (Read in for all dihedral angles holding blade angle constant)



$0 \leq \phi \leq 90$

$0 \leq \theta \leq 180$

*All input is on 7F10.2 Format

The effective absorptance table is read in only once. In the case of stacked cases the program loops back to this point to read the 2nd and subsequent cases.

B. Description of Louver Panel and Emitting Panel*

A**	XP	YP	XNXP	XNXP	SIE	EP	Card 1
B	XL	YL	XNXL	XNYL	C	THEMIN	Card 2
THEMAX	THENC						Card 3

Card 4 Thru - Table of Temperatures** for emitting panel. Read-in is in rows from left to right starting with the top row. Number of temperatures must be equa XNXP * XNYP

C. Computer Output

The computer output includes a listing of all input parameters. Then, for each blade angle of interest, the blade angle and the corresponding average heat absorption rate, Q, of the louver panel is printed out. This heat absorption rate has the units of BTU/HR FT^2.

*See Figure 8 for legend of input.
**All lengths are in feet, temperatures are ^oR

D. DIGITAL COMPUTER PROGRAM LISTING


```
      DIMENSION PITBL(20),THTBL(40),ALTBL(800),TP(20,20)
      DIMENSION C(100)
      READ (5,100) XPITBL,XTHTBL
      NPITBL = XPITBL
      NTHTBL = XTHTBL
      NALTBL = NPITBL*NTHTBL
      READ (5,100) (PITBL(J),J=1,NPITBL)
      READ (5,100) (THTBL(J),J=1,NTHTBL)
      READ (5,100)  (ALTBL(I),I=1,NALTBL)
    5 READ (5,100) A,XP,YP,XNXP,XNYP,SIE,EP
      WRITE(6,102) A,XP,YP,XNXP,XNYP,SIE,EP
  102 FORMAT(4H1 A=  F6.2,5X,3HXP= F6.2,5X,3HYP= F6.2,5X,5HXNXP= F4.0
     1,5X,5HXNYP= F4.0,5X,4HSIE= F5.1,5X,3HEP= F6.3//)
      READ (5,100) B,XL,YL,XNXL,XNYL,C,THEMIN,THEMAX,THEINC,XISO,TEMP
      WRITE(6,103) B,XL,YL,XNXL,XNYL,C,THEMIN,THEMAX,THEINC
  103 FORMAT(4H  B= F6.2,5X,3HXL= F6.2,5X,3HYL= F6.2,5X,5HXNXL= F4.0,5X,
     15HXNYL= F4.0,5X,2HC= F6.2//2X,7HTHEMIN= F6.1,5X,7HTHEMAX= F6.1,5X,
     27HTHEINC= F6.1// 50X,19HPANEL TEMPERATURES      //)
      NTHE = (THEMAX-THEMIN)/THEINC+1.
      RSIE = ABS(SIE*.0174533)
      RZETA = (90.-ABS(SIE))*.0174533
      NXP = XNXP
      NYP = XNYP
      NXL = XNXL
      NYL = XNYL
      IF(XISO.NE.0.) GO TO 20
      READ(5,100) ((TP(I,J),I=1,NXP),J=1,NYP)
      GO TO 22
   20 DO 21 I=1,NXP
      DO 21 J=1,NYP
   21 TP(I,J) = TEMP
   22 WRITE(6,104)((TP(I,J),I=1,NXP),J=1,NYP)
  104 FORMAT(2X,10F11.3)
      DXL = XL/XNXL
      DYL = YL/XNYL
      DXP = XP/XNXP
      DYP = YP/XNYP
      COSZ = COS(RZETA)
      SINZ = SIN(RZETA)
      A1 = DXP*DYP
      A2 = DXL*DYL
      SIEM = 1.
      IF (SIE.LT.0.) SIEM=-1.
      XLS = B+SIEM*SIN(RSIE)*XP/2.+DXL/2.
      XPS = DXP/2.
      YLS = (X P*COS(RSIE)/2.)-YL/2.+DYL/2.+C
      YPS = A+DYP/2.
      X1 = XLS
      X2 = XPS
      Y1 = YLS
      Y2 = YPS
      DO 8 M=1,NTHE
    8 C(M) = 0.
      DO 1 I=1,NXL
      DO 2 J=1,NYL
      DO 3 K=1,NYP
      DO 4 L=1,NXP
      EBP = EP*.1714E-08*TP(L,K)**4/3.1416
```

```
 XA = X1-SIEM*X2*COSZ
 XB = Y1-X2*SINZ
 XC = ABS(X1*SINZ-Y1*COSZ*SIEM)
 XD = (Y2**2+XA**2+XB**2)
 XX = ABS(XA/Y2)
 DHA = ATAN(XX)*57.2956
 THEL = THEMIN
 DO 6 M=1,NTHE
 THE = THEL
 IF(SIEM*Y1*COSZ/SINZ.GT.X1) THE=180.-THEL
 ALPHA = DI(PITBL,THTBL,ALTBL,DHA,THE ,NPITBL,NTHTBL,INDX,INDY,1,
11,1)
 Q(M) = (EBP*XC*Y2*ALPHA*A1*A2/(XD**2))+Q(M)
 THEL = THEL+THEINC
 THEL = THEMIN
 X2 = X2+DXP
 X2 = XPS
 Y2 = Y2+DYP
 Y2 = YPS
 Y1 = Y1+DYL
 Y1 = YLS
 X1 = X1+DXL
 X1 = XLS
 DO 7 M=1,NTHE
 Q(M) = Q(M)/(XL*YL)
 WRITE(6,101) THEL,Q(M)
 THEL = THEL+THEINC
 FORMAT(10X,6HTHETA= F6.1,5X,2HQ= F6.1)
 GO TO 5
 FORMAT (7F10.2)
 END
```

APPENDIX B

Revised Input-Output for Main Louver Program

The original digital computer program for analysis of louvers in a solar environment has been modified. The new program includes analysis of internal louvers, input from diffusely emitting panels and the ability to investigate several different base temperatures at the same time. A detailed description of the new input-output is presented here.

A. Computer Input

The computer input consists of:

COMMENT OR IDENTIFICATION							CARD 1
RADCON	THEMIN	THEMAX	THEINC	PHIMIN	PHIMAX	PHIINC	CARD 2
RSO1	RSO2	RSO3	RTO1	RTO2	RTO3	ET1	CARD 3
ET2	ET3	XNT	XPRINT	XPLOT	Q3IN	QSIN	CARD 4
ET4	ET5	ETS	ALS				CARD 5
T3(1)						T3(7)	CARD 6
T3(8)		T3(10)					CARD 7
XQ3IN(1)						XQ3IN(7)	CARD 8
XQ3IN (8)						XQ3IN(14)	CARD 9
XQ3IN(15)				XQ3IN(19)			CARD 10

RADCON - solar radiation intensity (BTU/HR-FT^2)

THEMIN - Minimum blade angle of interest (if it is 0 calculations are based on .1 degree)

THEMAX - maximum blade angle of interest

THEINC - size of increments in going from THEMIN to THEMAX (must be of such a magnitude that the total number of increments will not exceed 19)

PHIMIN - minimum solar angle of interest

PHIMAX - maximum solar angle of interest

PHIINC - size of increments in going from PHIMIN to PHIMAX (must be of such a magnitude that the total number of increments will not exceed 38)

RSO1,RSO2,RSO3 - solar reflectance of surface 1, 2, and 3 respectively

RTO1,RTO2,RTO3 - terrestrial reflectance of surface 1, 2, and 3 respectively

ET1,ET2,ET3 - emittance of surface 1, 2, and 3 respectively

XPRINT - -1. print results for all blade angles holding solar angle constant

+1. print results for all solar angles holding blade angle constant

0. both of above options

XPLOT - -1. plot net heat dissipation and blade temperature vs. blade angle holding solar angle constant

+1. plot net heat dissipation and blade temperature vs. solar angle holding blade angle constant

0. do not plot

XNT - Number of base temperatures to be examined

Q3IN - if greater than 0. heat input to the base (surface 3) will be read in for each blade angle for external louvers. Therefore the number of pieces of data must equal $\frac{\text{THMAX} - \text{THEMIN}}{\text{THENIC}} + 1$ not to exceed 19.

QSIN** - constant heat input to skin (internal louvers)

ET4 - inside skin emissivity (internal louvers)

ET5 - base emissivity (internal louvers)

ETS - exterior skin emissivity (internal louvers)

T3 (J) - base temperature (^{o}R) number of temperatures read is determined by <u>XNT</u>

XQ3IN(J)*** - heat input to base of external louvers for each blade angle. Number of items read is determined by the number of blade angle increments.

$$\frac{\text{THEMAX} - \text{THEMIN}}{\text{THEINC}} + 1$$

If the 1401 plot routine is used one additional card is needed for <u>each</u> base temperature.

** Heat inputs are in addition to solar input
*** Heat inputs are in addition to solar input

Column	1	Blank
Column	2	Period
Column	3	Plot character for internal louvers
Column	4	Plot character for external louvers
Column	5	Plot character indicating off scale point
Column's 11-20		Full scale for internal louvers
Column's 21-30		Full scale for external louvers

B. Computer output

The printed output consists of:

(1) identification or comment card

(2) input parameters

(3) total imaged view factors

(4) heat balance and equilibrium temperature data

The legend for the printed output is as follows,

FMNT - total terrestrial imaged factor from surface M to surface N

FMNS - total solar imaged view factor from surface M to surface N

THETA - blade angle

PHI - solar angle

A3s - solar energy absorbed by the base (BTU/HR-FT^2)

A312 - terrestrial energy absorbed by the base originating at the blade (BTU/HR-FT^2)

A303 - terrestrial energy abosrbed by the base originating at the base (BTU/HR-FT^2)

A3T - total energy absorbed by the base (BTU/HR-FT^2)

ES - solar energy striking the base which is reflected out of the system (BTU/HR-FT^2)

A12S - solar energy absorbed by the blades (BTU/HR-FT^2)

T12 - equilibrium temperature of the blades (^oR)

QNET - net heat dissipated by the base ($BTU/HR-FT^2$) for external louvers

QNET1 - net heat dissipated by the base ($BTU/HR-FT^2$) for internal louvers

(NOTE: POSITIVE QNET MEANS HEAT TRANSFERED AWAY FROM THE BASE, NEGATIVE QNET MEANS HEAT ABSORBED BY THE BASE)